Symptoms, Vascular Anatomy and Endovascular Treatment of Spinal Cord Arteriovenous Malformations

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Summary

The purpose of this study is to evaluate the symptoms, anatomy and efficacy of embolization of spinal cord AVMs (SCAVMs). We performed retrospective analysis of 108 SCAVMs consisting of 38 pediatric and 70 adult cases. They included 81 nidus (26 pediatric) and 27 fistulous (12 pediatric) AVMs. Hemorrhage occurred in 74% of pediatric and 62% of adult cases with multiple hemorrhages in 54% of pediatric and 42% of adult cases. Fistulous AVMs hemorrhaged more frequently in children than adults (75% vs. 13%). 75 cases were treated with embolization alone, 10 with surgery and embolization, 2 with embolization following radiation and 12 with surgery alone. 9 patients received no treatment. In 79 of 87 embolized patients, acrylic was utilized either alone (49) or in combination (30) with other materials. Embolization was attempted 156 times in 93 patients. Complete obliteration by embolization was obtained in 17 cases. If complete obliteration was not possible, partial targeted embolization was performed, aiming at dangerous anatomic structures such as aneurysms. During the follow-up period (mean: 34 months), hemorrhage was observed in only 2 cases. Although technical complications such as dissection or vasospasm occurred on 19 occasions, only 4 resulted in aggravation of neurological symptoms. Of the 21 sessions in which worsening of symptoms occurred after embolization, 10 resulted in per-

manent deficits and eight of these occurred prior to 1990. SCAVMs have a poor functional prognosis due to frequent hemorrhage if untreated. Embolization with acrylic is feasible as the first choice of treatment. Provocative test and electrophysiological monitoring have improved safety. Partial targeted embolization is effective in preventing hemorrhage.

Introduction

While spinal cord arteriovenous malformations (SCAVMs) are rare, there has been much controversy regarding their classification and treatment. In 1992, one of our authors (AB), reported on our early experience with SCAVMs with review of the literature, which was one of the few publications involving a large series¹. Since that time, there has been significant advancement in endovascular treatment of SCAVMs, including monitoring system. We retrospectively reviewed our cases of SCAVMs, including presentation, treatment, outcome and follow up, and compared management results before and after 1990.

Material and Methods

We performed retrospective analysis of 108 intradural spinal cord AVMs including perimedullary arteriovenous fistulas (AVFs).

Results

Of the 108 patients, there were 49 males and 59 females. Thirty-eight patients presented with symptoms at or before the age of 18 and were therefore classified as pediatric. The mean age of presentation of all patients was 26 years old. The age of presentation of pediatric cases ranged from 0 to 18 years old with the mean of 10 years. The age of presentation of the adult cases ranged from 19 to 76 years old with the mean of 35 years old. 39 AVMs were located at the cervical level and 69 at the thoracic and lumbar level. Of the 27 spinal AVFs reviewed, 19 were single hole fistulas and 8 had multiple fistulas. Pediatric AVFs tended to be multiple and high flow. Adult AVFs tended to be single and slow flow. All slow flow single hole fistulas (so called type IVa) were in the adult population and presented with progressive neurological deficits without hemorrhage.

Associated diseases were noted in several patients: metameric AVM in 12 patients, Osler-Rendu-Weber syndrome in 1, Klippel Trenaunay Weber syndrome in 1, skin pigmentation in 2 and factor VIII deficiency in 1.

The most common presentations were hemorrhage and neurological deficits. Sixty-three (58%) patients presented with hemorrhage. While 26 patients (24%) presented with progressive neurological deficits, 10 (9%) presented with non-progressive neurological deficits with pain and 8 (7%) with non-progressive neurological deficits without pain. One patient (<1%) presented with pain only.

Of the 71 patients (66%) who experienced at least one hemorrhage, 33 (46%) had multiple hemorrhagic episodes. There is no difference in hemorrhage rate between adult and pediatric nidus-type AVMs (75% and 73%, respectively). However, adult AVFs had lower rate of hemorrhage (13%) compared to pediatric AVFs (75%).

The mean age at the initial treatment was 16.5 years for the pediatric cases and 40 years for adult cases. In both pediatric and adult cases, there was, on the average, approximately 5 years of delay between the onset of symptoms and the initial treatment. Seventy-five patients were treated with embolization alone, 10 with combination of embolization and surgery, 2 with embolization following radiation and 12 with surgery alone. Nine patients received no treatment either because treatment was not

recommended or failed. In 79 of 87 embolized patients, acrylic was utilized either alone (49) or in combination (30) with other materials such as coils or particles. Particles were the only embolic agents used in 6 patients and coils were used alone in one patient.

Initially we performed embolization procedures under local anesthesia with neuroleptic analgesia, using only cortical somatosensory evoked potentials (SEPs) monitoring². Currently however, the procedure is performed under general anesthesia with both SEPs and motor evoked potentials (MEPs) monitoring. For recording of MEPs, we use transcranial stimulation of the motor cortex and recordings from the electrodes inserted into the muscle. The details of these monitoring methods are described elsewhere^{3,4}.

The results of embolization are shown on table 1. Ninety-three patients underwent endovascular embolization in 156 sessions, among which 15 sessions were aborted due predominantly to technical difficulties. Complete embolization was obtained in 17 cases including 13 AVFs. Subtotal (over 90%) occlusion was obtained in 30 cases. Thirty-nine cases resulted in partial occlusion.

Embolization was attempted but failed in 6 cases. Since it is often difficult to obtain complete obliteration of nidus-type SCAVMs, we often perform target embolization in order to close at least associated dangerous vascular anatomy such as aneurysms.

Technical complications occurred in 19 embolization sessions and included 5 dissections, 8 extravasations (4 extraspinal), 3 cases of vasospasm, 2 spinal seizures and 1 vertebral artery occlusion. Worsening of symptoms occurred in only 4 of these cases and included 1 transient deficit.

Worsening of symptoms after embolization occurred in 21 (13%) of the 156 sessions (table 2). Worsening of symptoms was permanent in 10 (6%) cases and temporary in 11. Comparing data before and after 1990, there has been a significant decrease in symptomatic complications since 1990, especially those resulting in permanent deficits.

The follow-up period after the initial treatment ranged from 1 month to 221 months with a mean of 34 months. Only 2 patients experienced hemorrhage during this follow-up period. Both patients were treated in the early

1980's and both bled after partial occlusion of their SCAVM. One patient had a single hole fistula which was subsequently completely occluded by a second embolization procedure. The other patient hemorrhaged after partial occlusion of a nidus-type SCAVM which was embolized using PVA particles.

Discussion

SCAVMs are a distinct entity and should be clearly separated from the spinal dural arteriovenous fistulas (SDAVFs). They tend to present at a young age with hemorrhage and are prone to recurrent hemorrhage if untreated. The incidence of hemorrhage was reported to be 31% as the initial symptom and 51% by the time of diagnosis¹. Our series showed an even higher incidence; 58% as the initial symptom and 66% before treatment. It has previously been reported that once a patient hemorrhages, the incidence of recurrent hemorrhage is very high¹.

Our data supports this observation with a 46% recurrent hemorrhage rate. Another distinct feature regarding clinical presentation of SCAVMs concerns slow-flow perimedullary fistulas. They usually present with progressive neurological deficits without hemorrhage in the middle age adults. This factor contributes to the lower incidence of hemorrhage in adult AVFs compared to pediatric AVFs⁵. High flow AVFs had a similar incidence of hemorrhage as nidus-type SCAVMs.

We believe that endovascular embolization is the treatment of choice for the most SCAVMs. The only exception is slow-flow, perimedullary AVFs located at the conus or filum terminale.

These lesions are usually supplied by a relatively small anterior spinal artery which makes endovascular embolization difficult as opposed to surgery which is relatively easy in this area. We also believe that acrylic material is the best embolic material for the nidus type SCAVMs because of its liquid nature allowing penetration into the nidus and its long lasting occlusive effect.

This material can be used in combination with other materials such as particles or coils. In the past, we used acrylic materials predominately for posterior spinal artery (PSA) feeders and particles for anterior spinal artery (ASA) feeders. We have been progressively using

more acrylic material for ASA feeders because improved microcatheters and microguidewires have allowed distal superselective catheterization into ASA feeders. For AVFs, coils are sometimes the best embolic material.

Despite rapid technical advancement, the rate of complete obliteration of nidus type SCAVMs by embolization alone is low. This is due to both the long distance from the origin of the ASA or PSA feeder to the nidus as well as the rich anastomosis among the vessels within and on the surface of the spinal cord. For those AVMs in which complete obliteration is difficult, we perform partial target embolization focusing on the dangerous vascular anatomy such as aneurysms. The very low rate of hemorrhage after partial embolization, compared to the high incidence of repeated hemorrhage prior to treatment proves that this target partial embolization is effective in preventing hemorrhage⁵. The low incidence of hemorrhage after

Table 1 **Result of embolization for SCAVMs**

Obliteration	
Complete	17*
Subtotal	(>90%)30
Partial	(<90%)39
Aborted	6
Unknown	1
Total	93**
* = Including 13 AVFs and 4-nidus type AVMs; ** = Total 156 sessions including 15 aborted sessions	

Table 2 **Symptomatic complications of embolization for SCAVMs**

	<=1990	>1990	Total
Total No of Sessions	72	84	156*
Temporary deficits	5 (7%)	6 (7%)	11 (7%)
Permanent deficits	8 (11%)	2 (2%)	10 (6%)
Total	13 (18%)	8 (10%)	21 (13%)
* = Including 15 aborted sessions			

partial embolization of SCAVMs has also been reported by other authors⁶.

Comparing data before and after 1990, the rate of symptomatic complications, especially permanent deficits, has significantly decreased since 1990. This is most likely due to advancement of technique, equipment and understanding of the disease. The improvement in electrophysiological monitoring systems^{7,8} also contributes to the improved outcome.

Conclusions

SCAVMs have a high rate of multiple hemorrhages and their functional prognosis is poor if untreated. Embolization is the first choice of treatment for SCAVMs. Partial embolization by target embolization is effective to prevent hemorrhage. Acrylic is the preferable embolic agent for nidus type SCAVMs and can be used in combination with other materials.

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